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ECHINODERMA (PART II.) AND  
ENTEROPNEUSTA.

LARVAE OF ECHINODERMA AND ENTEROPNEUSTA.

BY

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WITH TWO PLATES.



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# ECHINODERMA (PART II.) AND ENTEROPNEUSTA.

## LARVAE OF ECHINODERMA AND ENTEROPNEUSTA.\*

BY E. <sup>Ernest</sup>W. <sup>William</sup>MACBRIDE, D.Sc., LL.D., F.R.S.,

*Professor of Zoology in the Imperial College of Science and Technology, London, S.W.*

WITH TWO PLATES.

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### I.—INTRODUCTION.

THROUGH the kindness of my friend Dr. S. F. Harmer, F.R.S., Director of the Natural History Departments of the British Museum, I obtained the privilege of examining and reporting on the Echinoderm and Enteropneust larvae brought back by the "Terra Nova" Expedition.

A considerable number of specimens were collected ; but they all belong to four species, of which only one, a *Bipinnaria*, is new. Two species of *Auricularia* are

\* Manuscript received July 24, 1918 [S. F. H.].



represented in the collection, and one of *Tornaria*. Of one of the species of *Auricularia*, specimens in different stages of growth were obtained, and I was thereby enabled to settle some disputed points in the embryology of Holothurioidea which are of general interest. As Mr. Simpson and myself (8) had formerly described Echinoplutei and Ophioplutei from the same part of the world, all four types of Echinoderm larvae have now been recorded by me from this region of the Antarctic.

## II.—DISTRIBUTION.

The specimens were captured at two groups of stations, the members of each group being close to one another, so that all the larvae are derived from two localities, of which only one was Antarctic. The other locality is in the vicinity of Three Kings Islands, a group of islets situated a short distance north of North Cape, New Zealand. In this second locality the *Tornaria* and one of the species of *Auricularia* (*A. nudibranchiata*) were obtained. The Antarctic locality comprises a group of stations situated between  $69^{\circ} 50'$  and  $72^{\circ}$  S., and between  $166^{\circ}$  and  $168^{\circ} 50'$  W. The area within which these stations lie is therefore roughly a rectangle of two-and-a-half degrees of longitude in width, and of two-and-a-half degrees of latitude in height.

## III.—PRESERVATION AND METHODS OF PREPARATION.

In all the bottles, except one, which were handed over to me, the larvae were contained in formalin solution. In one case the specimens had been placed in picric acid, but they were in fragments when the bottle came into my hands. All the larvae, therefore, which I was able to examine, had been preserved in formalin.

This circumstance had a determining influence on the methods of preparation which I adopted. It is a well-known fact that formalin gives poor results so far as histological structure is concerned, but that it renders the tissues very transparent. Hence all the specimens which I examined were stained in bulk and mounted whole. Two stains were employed, both in strong alcoholic solution, *viz.*: eosin and light green. The latter, which, like eosin, is an aniline dye, gave far more satisfactory results than eosin because it produced a much more intense coloration. After being stained the specimens were transferred to absolute alcohol, to which a few drops of oil of cloves were added every day for a couple of weeks. Then the mixture of oil and alcohol was placed in an open vessel and allowed to evaporate, and, as a result, in a couple of days only pure oil of cloves remained. To this an equal amount of solution of Canada balsam in Xylol was added, and in this mixture the specimens were left for a day, after which they were ready to be transferred to pure balsam on the slides. It is to be noted that formalin readily becomes partially oxidized to formic acid, and so any calcareous structures which the specimens originally contained had been dissolved before they came into my hands.

## IV.—DESCRIPTION OF THE SPECIES.

## ECHINODERMA.

## A. HOLOTHURIOIDEA.

1. *Auricularia antarctica*, MacBride. Figs. 1-3, 5, 6.

Station 270.	69° 51' S., 166° 17' W.,	surface to 600 metres.	Two large specimens.
„ 272.	71° 35' S., 166° 11' W.,	80 metres.	Several specimens.
„ 274.	71° 29' S., 166° W.,	80 metres.	Many specimens.
„ 275.	„ „	160 metres.	Many specimens.
„ 281.	71° 41' S., 166° 47' W.,	80 metres.	Many specimens.
„ 283.	71° 39' S., 166° 47' W.,	80 metres.	Many specimens.
„ 285.	71° 49' S., 167° 32' W.,	surface to 600 metres.	Two large specimens.
„ 288.	71° 59' S., 168° 43' W.,	60 metres.	Many specimens.

This species was originally described by me from a single specimen (9). It was subsequently found by Mortensen amongst the larvae collected by the German South Polar Expedition (14). In the collection which is the subject of the present memoir it is represented by numerous specimens of all sizes, from about .8 mm. to 5.0 mm. in length.

The diagnostic characters of *A. antarctica* as originally determined by me were three: *viz.* (1) The presence of numerous calcareous “wheels”; (2) the great extension of the post-oral loop of the longitudinal ciliated band, which goes so far forward that it is separated from the prae-oral loop by a narrow groove in which the mouth lies; (3) the great width of the larva from front to back (Fig. 2), as a result of which the anterior pole, *i.e.*, the spot where the prae-oral loop leaves the main portion of the longitudinal ciliated band, is situated far behind the mouth instead of being directly anterior to it, as is the case with most *Auricularia* larvae. To these characters I can now add a fourth: *viz.*, the intestine is produced into two well-developed pouches directed ventrally, between which the ventral curvature of the stomach is contained. These pouches (*int. l.*) are well seen in Figs. 3, 2, and 6.

The characteristic calcareous “wheels” had been dissolved by the acidity of the preserving fluid, but the other two characteristics are very strongly marked, and quite sufficient to determine these larvae as belonging to *A. antarctica*. In many of the specimens little disc-shaped groups of cells can be made out (*calc.*, Figs. 1 and 3) which represent the organic bases of the vanished “wheels.”

The exact mode of development of the coelom in Holothurioidea has been the subject of considerable differences of opinion. The older authors described its first beginning as a sac given off from the blind apex of the archenteron, as in other groups of Echinoderms (Selenka, 17, 18). This sac speedily acquired a communication with the exterior by the development of a tubular extension, the PORE-CANAL, which fused with the dorsal ectoderm. In some species, at any rate, the pore-canal was developed before the alimentary canal had been completed by the union of the stomodaeum with the archenteron.

According to Selenka (18) and Metschnikoff (10) the coelomic sac then became divided into anterior and posterior portions, of which the former gave rise to the HYDROCOELE or rudiment of the water-vascular system, whilst the latter became divided transversely into two parts which became applied to the right and left sides of the alimentary canal, and constituted the posterior coelomic sacs of the larva (Fig. 5, *r. p. c.*, *l. p. c.*). The critical stages in which the posterior portion of the single sac became changed into right and left posterior coelomic sacs were first figured by Metschnikoff (10).

Bury, who examined stages in the development of the larva of *Synapta digitata* (1), came to a different conclusion as to the manner in which the coelomic sac developed. According to him, when it has become divided into anterior and posterior portions the anterior division does not become directly converted into the hydrocoele. The hydrocoele on the contrary grows out as a bud from its hinder aspect, which remains connected with the main sac, termed by Bury the ANTERIOR COELOM. The narrow neck of connection between hydrocoele and anterior coelom was identified by him with the PRIMARY STONE-CANAL. Bury compared the anterior coelom of *Synapta* to the axial sinus of Asteroidea, and surmised that it gave rise to the "internal madreporite" of the adult Holothuroid.

Bury's view has not been confirmed by subsequent workers. Ludwig (5) examined the development of *Cucumaria planci*, and came to the conclusion that the anterior portion of the primitive coelomic sac was directly converted into the hydrocoele; in later stages he found what he termed an "ampulla," *i.e.*, a thin-walled expansion on the course of the pore-canal; but he maintained that this was a secondary formation. Newth (15), who worked at *Cucumaria saricola*, came to much the same conclusion. Clarke (3), who studied the development of *Synapta viripara*, also describes the anterior division of the coelomic sac as being directly converted into the hydrocoele. Now it is to be remembered that *Synapta digitata* is the only species of Holothuroid with a typical larva, the complete life-history of which has been worked out.

The species of *Cucumaria* have yolky eggs, with shortened life-histories, and larvae which do not show the features of an *Auricularia*; whilst the young of *Synapta viripara*, as the name of the species implies, develop into the adult form inside the maternal body. We are therefore permitted to surmise either that the observers who worked with these rapidly developing eggs overlooked stages which Bury was able to see in the slowly developing larvae, or else that these stages were actually suppressed in the more modified development. For instance, one might imagine that what Clarke, Ludwig, and Newth regard as a "pore-" or "stone-canal," connecting the incipient hydrocoele with the exterior, might represent the vesicle which Bury terms the anterior coelom in a collapsed form.

Under these circumstances it was a pleasure to me to discover that the specimens of *Auricularia antarctica* in the collection constituted a series from which it was possible to reconstruct the entire history of the coelom. In the youngest specimen the coelom is a simple rounded sac opening to the exterior by a pore-canal. In a specimen



slightly older, such as is shown in Fig. 3, the first rudiment of the hydrocoele (*hy.*) can be made out as a slight thickening on the posterior border of the coelomic sac. In a slightly older larva (Fig. 1) the hydrocoele has not advanced much in development, but from its hinder aspect a small stalked cellular bud can be seen growing out (Fig. 1, *post. c.*). This is the rudiment of the *posterior coelom*. Fig. 2 represents a more advanced larva viewed from the side. In it the hydrocoele has become as large as the anterior coelom (as the primitive coelomic sac may now be termed), and is delimited from it by a constriction (Fig. 2, *hy.*). The posterior coelom has now developed into a long band lying at the side of the stomach. This stage corresponds with that represented in text-fig. 1 in Mortensen's latest paper (14), but Mortensen has quite misunderstood it. He overlooked the rudiment of the posterior coelom altogether, and has figured a sac entirely detached from the anterior coelom as the posterior enterocoele. This sac, which lies above the junction of the stomach and intestine, has nothing to do with the coelom, but is one of the intestinal pouches characteristic of *Auricularia antarctica*. In Fig. 6, a still older larva is represented, seen from the dorso-lateral aspect. The hydrocoele has now begun to curve ventrally round the oesophagus. The rudiment of the posterior coelom shows a constriction tending to divide it transversely into front and hind portions. Of these the first is the rudiment of the left posterior coelom, and the hinder one is the rudiment of the right posterior coelom. This stage, as mentioned above, has been figured by Metschnikoff (10) in his description of the *Auricularia* of *Synapta digitata*, but has not been described in connection with any other *Auricularia*, although Clarke has described it in the EMBRYO of *Synapta vivipara*.

In Fig. 5 is represented a dorsal view of one of the oldest larvae in the collection. The hydrocoele (*hy.*) has now begun to develop thickened lobes, which are the rudiments of the primary tentacles; it is sharply marked off from the anterior coelom (*ant. c.*), with which it is connected by a strongly constricted neck of communication. The two posterior coelomic sacs (*r. p. c.*, *l. p. c.*) have now taken up their definitive positions to the right and left of the stomach.

A peculiar larval nervous system was described by Semon (19) in the larva of *Synapta digitata*. This system consisted of two bands of fibrils running from the corners of the mouth down the grooves which separate the post-oral loop from the main longitudinal portions of the ciliated band. This nervous system is present in *Auricularia antarctica* (Figs. 1 and 2, *l. nerv.*), but it seems to be shorter than in the *Auricularia* of *Synapta digitata*.

It will be seen that my survey of the specimens of *Auricularia antarctica* entirely confirms Bury's account of the development of the coelom in *Synapta digitata*; and this account may therefore, I think, be taken as correctly describing the normal sequence of events in Holothurioidea. We have evidence in other groups of Echinoderms that the normal processes may become profoundly modified as a result of the hurrying on of development, and in this way we may probably account for Clarke's, Ludwig's, and Newth's results.

The question as to which species, or even family, of Holothurioidea *Auricularia*

*antarctica* belongs is one which is at present insoluble. In my original description (9) I suggested that *Auricularia antarctica* might be the larva of some member of the sub-order Synaptida, since calcareous wheels are characteristic of many genera belonging to that division, though not of *Synapta* itself. Mortensen dissents from this view on the following grounds, *viz.*: (1) Very few Synaptida are recorded from the Antarctic region; (2) *Auricularia antarctica* shows many points of resemblance to *Auricularia nudibranchiata* (*v. infra*), and the latter species is regarded by Mortensen as the larva of one of the Elasipoda (Elpidiida); (3) the Elasipoda sometimes possess "wheels" amongst their calcifications.

When dealing with *A. nudibranchiata* I shall give grounds for regarding its supposed Elasipodan affinities to be entirely unfounded, though I agree with Mortensen in recognising some striking resemblances in structure between these two species of *Auricularia*. I adhere, however, to my original suggestion for this reason. According to Ludwig (6) the wheels of Elasipoda differ from those of Synaptida in having the hub perforated; and on this account he regards them as more primitive structures. Now although I described the wheels of *Auricularia antarctica* as having perforated hubs, yet a renewed examination of the type specimen in the Natural History Museum has convinced me that I was mistaken. What I took for holes appear to be glittering calcareous asperities, and hence Mortensen was right in casting doubt on my original description in regard to this point. But I utterly fail to understand why he states that perforated hubs are unknown, and why he omits to observe that wheels with solid hubs are found in Synaptida only. Had my original statement been confirmed there would have been some ground for a suggestion of Elasipodan affinity. On the ground that a young Holothuroid, which he diagnoses as a Synallactid, was obtained by the German Expedition, Mortensen finally inclines to the belief that *A. antarctica* may be the larva of this form. As no Synallactid is known to have wheels, this suggestion may be regarded as very improbable. Synaptida are burrowing Holothuroids, and must, therefore, in most cases evade the dredge; and the fragments of the two forms already recorded from the Antarctic area probably give no correct suggestion of their abundance. All the specimens of *Auricularia antarctica* were obtained at depths of between 80 to 160 metres below the surface; the parent must, therefore, be an inhabitant of deep water, and the suggestion that it is a mud-inhabiting Synaptid gains in probability.

## 2. *Auricularia nudibranchiata*, Chun. Fig. 4.

Station 92, from summit, Great King, S. by W., 24 miles (off N. end of New Zealand), surface. One specimen.

In 1896 Chun (2) described a new form of *Auricularia*, of which he captured many specimens in the vicinity of the Canary Islands. This larva was characterised by the extraordinary complication of the ciliated band, the primary processes of which were bent into numerous secondary processes, which gave to the creature the appearance of a Nudibranch mollusc. For this reason Chun bestowed on it the name *Auricularia nudibranchiata*. The larva possessed three other characteristics: (1) It had embedded

in it numerous calcareous wheels; (2) the post-oral loop of the ciliated band extended so far forward that it was separated from the prae-oral loop only by a narrow groove; (3) the intestine was produced into a median ventral pouch extending forward beneath the stomach. Chun described the anterior division of the larval coelom as a large sac with finger-like outgrowths, which he interpreted as the rudiments of the water-vascular canals of the adult Holothuroid.

In 1911 Ohshima (16) described specimens of what he termed "a large *Auricularia* allied to *A. nudibranchiata*," which he captured off the south coast of Japan. The larvae appear to me to be identical with Chun's species, but to represent a more advanced stage of its development than Chun secured. Ohshima points out that the ramifications of the anterior coelom described by Chun have nothing to do with the lobes of the hydrocoele, for in his larvae the hydrocoele was a clearly defined, thick-walled structure lying at the side of the oesophagus beneath the anterior coelom, with which it was connected by a narrow neck. In a word, the distinction between hydrocoele and anterior coelom, described by Bury in the larva of *Synapta digitata*, is equally clear in *Auricularia nudibranchiata*. The specimen of this remarkable larva captured by the "Terra Nova" Expedition is in an advanced stage of development, and measures at least a centimetre in length, being more than twice the length of Chun's oldest stage. On examining it I was able to confirm Ohshima's account, and to add certain details which are shown in Fig. 4. This figure represents only a portion of the monster, including the hinder part of the oesophagus, the front part of the stomach and the adjacent coelomic sacs. The anterior coelom can be seen to open to the exterior by a ciliated duct, THE PORE-CANAL (*p. c.*), situated at its posterior end. This duct runs along the wall of the coelom for some distance, and gives the impression of having been originally a groove in this wall which has become closed off. This is the way in which a considerable portion of the pore-canal is formed in the larva of *Asterina gibbosa*. In front and ventrally, the anterior coelom communicates with a well-marked hydrocoele, showing the thickened elevations which are the rudiments of its primary lobes.

When the posterior portion of this larva is examined, it is easy to see the structure described by Chun as a median ventral pouch of the intestine. It is, relatively to the size of the larva, of much less size than in the earlier stages described by Chun. Further, in my specimen it is seen not to be a single pouch, but to consist of a pair of closely adpressed pouches which, I have no doubt, are homologous with the intestinal pouches of *Auricularia antarctica*.

On the ground that a single intestinal diverticulum has been described in certain Elaspoda, Chun and Mortensen draw the conclusion that this larva belongs to the Elaspoda. This single diverticulum is supposed to be a rudimentary representative of the gill- (lung-) trees of other Holothurioidea; but the discovery that the pouch is paired deprives this argument of its ground, and *A. nudibranchiata* might be the larva of any Holothuroid with internal gills, if these pouches are the rudiments of gills. There is, however, grave reason for doubting this hypothesis. When examining a collection of post-larval young of Holothuroids from the Antarctic, which almost certainly

belonged to the genus *Cucumaria*, I discovered what appeared to be the rudiment of the gill-trees, which in this genus are extremely well developed. This rudiment, a single pouch-like outgrowth of the intestine, only appeared in the oldest specimens—in the younger there was no trace of it (9). It is, therefore, exceedingly unlikely that a rudiment of these gills should appear in the *Auricularia* larva; they probably only begin to develop when the cloacal function of sucking in and ejecting water has been established. I conclude, therefore, that the intestinal pouches of *A. antarctica* and *A. nudibranchiata* have nothing to do with gills; and, if this be admitted, there is no reason why *A. nudibranchiata*, like *A. antarctica*, should not be the larva of a Synaptid, to which group its wheels naturally ally it.

#### B. ASTEROIDEA.

##### 3. *Bipinnaria antarctica*, nov. Figs. 7, 8.

Station 274. 71° 29' S., 166° W., 80 metres. 11 specimens.  
 „ 284. 71° 49' S., 167° 32' W., 80 metres. 3 specimens.  
 „ 290. 72° S., 168° 17' W., 60 metres. Many specimens.

In the same locality, and at the same depths at which *Auricularia antarctica* was captured, numerous specimens were obtained of a large *Bipinnaria* in various stages of development, ranging from a stage in which no hydrocoele can be detected to one in which not only the lobes of the hydrocoele, but also the aboral spines of the future starfish are well developed. The calcareous matter of these spines had, of course, been dissolved by the acidity of the preservative; but the organic base of the spines remained, and their shapes were consequently well defined in the specimens.

A careful search through Mortensen's synopses of known Echinoderm larvae (12, 13) failed to disclose any species to which this *Bipinnaria* could be referred, and hence I feel justified in creating for its reception a new species, with the name *Bipinnaria antarctica*.

The new species is characterised by long arms, which do not attain, however, the proportionate length of those of the *Bipinnaria* of *Luidia*. Its most distinguishing feature is, however, the *crenulation* of the ciliated band, which is well shown in Figs. 7 and 8. This is a character which has so far been recorded of no species of *Bipinnaria*. It may be compared to the formation of secondary loops on the ciliated band of *Auricularia nudibranchiata*, and of secondary tentacles on the ciliated band of *Tornaria gmelchovi* (*v. infra*), but the folding is slighter than in the case of either of these two larvae.

This folding or crenulation of the ciliated band is confined to those portions of its course which are situated on the arms of the larva. Each of these arms has a groove on its surface bordered by ridges which are surmounted by the ciliated band. Underlying the groove are three bands of longitudinal muscle-fibres (Figs. 7 and 8, *long. musc.*), one in the centre and one on each side.

There are two main types of *Bipinnaria* larva which may be termed the *Asterias*-type and the *Luidia*-type respectively. Larvae of the first type have no median ventral



arm in front of the mouth; in their older stages they develop three peculiar club-shaped arms on the region of the prae-oral lobe, between the prae-oral ciliated band and the median dorsal arm. Such larvae are then termed *Brachiolaria*, and they can hold on to the substratum by these new arms. Eventually they fix themselves permanently by means of an adhesive disc situated in the centre of the three extra arms, and the whole front region of the larva is gradually absorbed. Larvae of the second type have a median ventral arm which carries a loop of the prae-oral ciliated band. So far as is known they never develop into *Brachiolaria*, and although the life-history of none of them has been completely worked out, yet the observations of M. C. Delap (4) on the larva of *Luidia* seem to indicate that, when metamorphosis approaches, the hinder portion of the larva containing the stomach and intestine, and surrounded by the circle of arm-rudiments, becomes amputated from the front half and sinks to the bottom as the future starfish, whilst the front half remains swimming.

As an inspection of Fig. 7 demonstrates, *Bipinnaria antarctica* belongs to the *Luidia* type of larvae, for the median ventral arm is well developed, and in the most advanced specimen no trace of *Brachiolaria* arms has appeared.

It will be noticed that each of the aboral plates of the future starfish carries two large conical spines. Now amongst the starfish described by Ludwig (7), in his description of the collection brought back from Cape Horn and Antarctic waters by the "Belgica," there occurred a species of the genus *Cheiraster* on which Ludwig bestowed the name *C. gerlachei*. Some very small specimens of this species were obtained, which must have metamorphosed only a short time before. In these young starfish the terminal plates covering the tips of the arms each bear two large conical spines resembling those borne by *Bipinnaria antarctica*. Although *Cheiraster gerlachei* was obtained in longitude 82 W., it was found at about the same latitude (about 70° S.) as the larvae; and as between the two localities there extends a comparatively short stretch of open Antarctic sea, it is quite likely that *Cheiraster gerlachei* inhabits the whole of this area, and therefore we may assign *Bipinnaria antarctica* to this species. *Cheiraster* belongs to the family Archasteridae, which is closely allied to the Astropectinidae to which *Luidia* belongs, and it is practically certain that it must have a larva of the *Luidia* type.

## ENTEROPNEUSTA.

### 4. *Tornaria grenacheri*, Spengel. Figs. 9, 10.

Station 130, off Three Kings Islands, N. end of New Zealand, surface. Two specimens.

Two specimens of a species of *Tornaria* were obtained by the Expedition in a haul made in the vicinity of Three Kings Islands, *i.e.*, in the same neighbourhood as that in which *Auricularia nudibranchiata* was obtained. One specimen was in process of metamorphosis, but the other was in the height of larval development, although unfortunately somewhat mutilated. The metamorphosing specimen is shown in Fig. 10.

It will be seen that the longitudinal ciliated band has almost entirely disappeared, but that the strong posterior transverse ciliated band has persisted. From an examination of the longitudinal ciliated band in the mutilated specimen, and of the vestiges of it in the metamorphosing larva, it is clear that this band was produced into secondary tentacle-like processes. It can also be seen that the stomach (*stom.*), instead of being, as in other species of *Tornaria*, a globular sac, is an elongated tubular organ. Now in respect of both these organs this larva agrees with a species termed by Spengel (20) *T. grenacheri*, which was captured in mid-Pacific, between the Sandwich and Marshall Islands, and we may therefore assign our larva to this species. Spengel gives the name *grenacheri* to the species because he regards it as absolutely identical with a larva captured by Prof. Grenacher, near the Cape Verde Islands in the South Atlantic; he also asserts that it is identical with a *Tornaria* first recorded by Weldon (21) from the Bahamas, the development of which was subsequently worked out by Morgan (11), who terms it the Nassau larva. Spengel also mentions that an extremely similar larva was captured by Driesch in the Indian Ocean. If all these larvae really belong to the same species, we should have to infer the existence of an Enteropneust worm with a distribution encircling the earth. When, however, we consider that *Auricularia nudibranchiata* has been captured both in the South Atlantic and the South Pacific, we see that it too must belong to some Holothuroid with an equally wide distribution. Now both Synaptida (wheel-bearing Holothuriodea) and Enteropneusta are creatures which burrow in sand and mud, and on bottoms like these at considerable depths, conditions must be extraordinarily uniform over enormous ranges, so that we should expect the species inhabiting them to be equally widely distributed. There is, therefore, nothing inherently improbable in Spengel's theory; but there are one or two points in the structure of the larva which we are discussing which make me doubt whether it is identical with the Nassau larva, although that larva doubtless belongs to an allied species. When we examine Morgan's figures we observe that the stomach in the Nassau larva, although elongated, is not so tubular as in the typical *T. grenacheri*. Moreover, Morgan figures in the metamorphosing Nassau larva the rudiments of the first gill-pouches, but no trace of a notochord. In our specimen no trace of gill-pouches can be detected, but a well-marked diverticulum is seen to arise from the oesophagus. The tip of this pouch (*uch.*) curves back towards the base of the anterior coelom or proboscis-cavity (*ant. c.*), and I think there can be no doubt that this is the rudiment of the notochord (Fig. 10). It appears more probable therefore that *T. grenacheri* and the Nassau larva belong to two distinct but allied species.

Fig. 9 is intended to elucidate a point in the anatomy of the *Tornaria* larva, of which I can find no clear account either in Spengel's or in Morgan's descriptions.

It is well known that in the adult Enteropneust there is a structure which has been variously termed "glomerulus" or "proboscis-gland." This is a modification of the epithelium of the posterior or basal wall of the proboscis-cavity, where this is indented by the notochord. The cells in this area become thickened and are richly supplied with blood-vessels, and it has been surmised with much probability that the

whole structure is an excretory organ. What seems clearly to be the beginning of this organ is shown both in Fig. 9 and Fig. 10 (*gl. ep.*).

In Fig. 9 the neighbourhood of the proboscis-pore (*d. p.*) is shown on an enlarged scale. It will be seen that the proboscis-cavity is prolonged into two postero-dorsal tubes or "horns" (*r. h.* and *l. h.*), of which only the left communicates with the exterior by the proboscis-pore. Beneath the right horn lies the completely closed pericardial sac (*per.*), which in life is contractile. The analogy of the proboscis-pore and the adjacent pericardial sac to the madreporic pore and the madreporic vesicle of Echinoderms (which in the *Bipinnaria* larva is contractile) has often been pointed out. Beneath the pericardium is a blood-space (Fig. 9, H) which becomes the heart of the adult; the roof of this space is formed by the contractile floor of the pericardial sac. Around this blood-space there is a crescentic mass of deeply-staining and obviously glandular tissue, which must be a modification of the ventro-lateral walls of the pericardial sac. To this structure I propose to give the name of HEART-GLAND (Fig. 9, *h. gl.*). The only reference to it in the works of Morgan and Spengel which I can find is a statement that the cells forming the lateral walls of the pericardial sac become "pear-shaped," and they seem to regard the structure as the first rudiment of the proboscis-gland; but the complete distinctness of the two structures is obvious from an inspection of either Fig. 9 or Fig. 10. We can only surmise that the heart-gland has some function in connection with the blood, and perhaps is an organ of internal secretion.

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Echinoderma, Part II, and Enteropneusta, Plate I.

## PLATE 1.

<i>Auricularia antarctica</i>	. . . . .	Figs. 1-3, 5, 6.
,, <i>nudibranchiata</i>	. . . . .	Fig. 4.

### List of Abbreviations employed.

<i>a. d.</i> antero-dorsal process of ciliated band. <i>ad. cil.</i> adoral ciliated band. <i>an.</i> anus. <i>ant. c.</i> anterior coelom. <i>calc.</i> cells forming organic basis of calcification. <i>hy.</i> hydrocoele. <i>int.</i> intestine. <i>int. d.</i> intermediate dorsal process of ciliated band. <i>int. l.</i> intestinal lobe. <i>l. n. n.</i> larval nervous system. <i>l. p. c.</i> left posterior coelom.	<i>m.</i> mouth. <i>m. p.</i> madreporic pore. <i>oes.</i> oesophagus. <i>p. c.</i> pore-canal. <i>p. d.</i> postero-dorsal process of ciliated band. <i>p. l.</i> postero-lateral process of ciliated band. <i>p. o.</i> post-oral process of ciliated band. <i>post. c.</i> posterior coelomic sac. <i>pr. o.</i> prae-oral process of ciliated band. <i>r. p. c.</i> right posterior coelom. <i>stom.</i> stomach.
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*The figures are described in the order of the ages of the larvae represented.*

- FIG. 3. —Ventral view of a young *Auricularia antarctica*, showing the first stages in the development of the hydrocoele (*hy.*); *calc.* organic bases of calcification. Magnification 22 diameters.
- FIG. 1. —Oblique ventral view of a somewhat older specimen of *A. antarctica*; *l. n. n.* larval nervous system; *post. c.* a bud of cells, growing from the posterior border of the hydrocoele, which is the first rudiment of the posterior coelomic sac. Magnification 22 diameters.
- FIG. 2. —A still older specimen of *A. antarctica* viewed from the left side; *int. l.* lobes of the intestine. The hydrocoele (*hy.*) is a large sac separated from the anterior coelom (*ant. c.*) by a constriction. The posterior coelomic sac (*post. c.*) is represented by a band of cells extending backwards over the stomach. All the processes of the longitudinal ciliated band are well seen. Magnification 22 diameters.
- FIG. 6. —Specimen of *A. antarctica*, slightly older than that shown in Fig. 2, viewed from the left dorso-lateral aspect. The posterior coelomic sac is in the act of dividing into right and left posterior coeloms (*r. p. c.*, *l. p. c.*). Magnification 22 diameters.
- FIG. 5. —One of the oldest specimens of *A. antarctica* viewed from the dorsal aspect. The hydrocoele (*hy.*) shows the beginnings of the primary lobes; it is sharply marked from the anterior coelom (*ant. c.*), with which it is connected only by a constricted canal. The posterior coelom is completely divided into right and left posterior coeloms, which are situated at the sides of the stomach. Magnification 22 diameters.
- FIG. 4. —A portion of the specimen of *Auricularia nudibranchiata* viewed from the dorsal aspect, showing oesophagus, stomach, and adjacent coelomic cavities; *p. c.* the pore-canal running along the posterior aspect of the anterior coelom. Magnification 16 diameters.

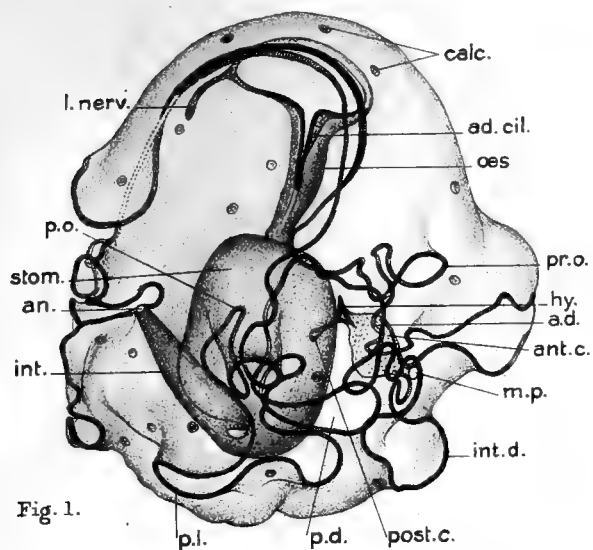


Fig. 1.

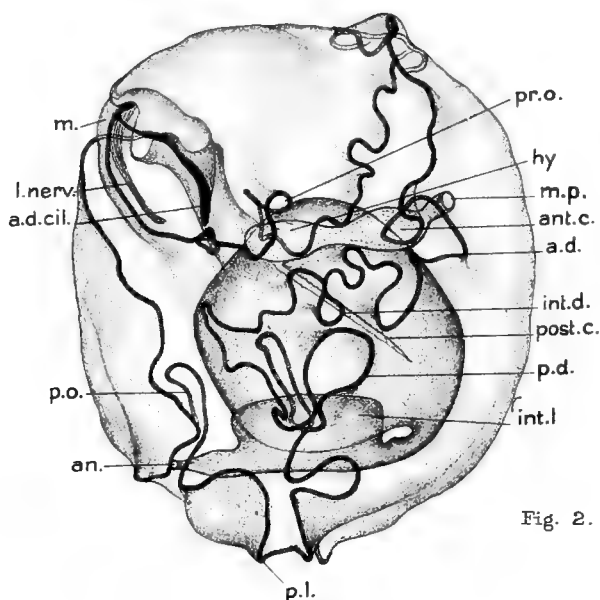


Fig. 2.

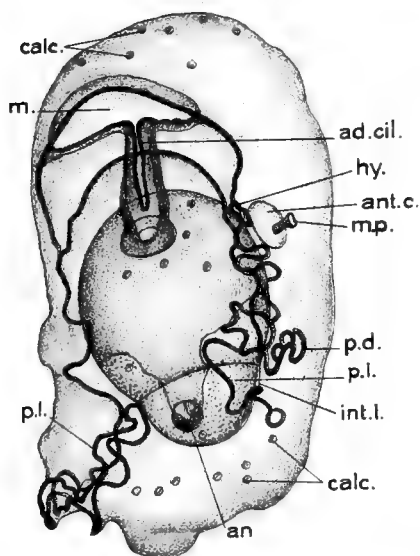


Fig. 3.

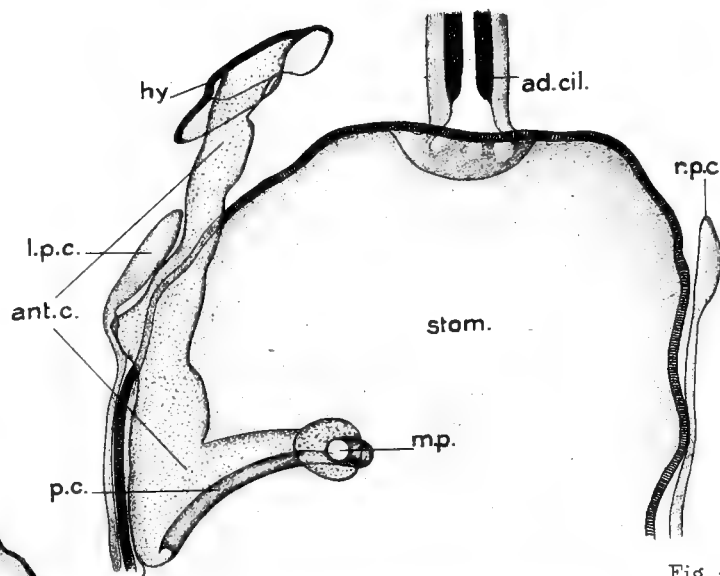


Fig. 4.

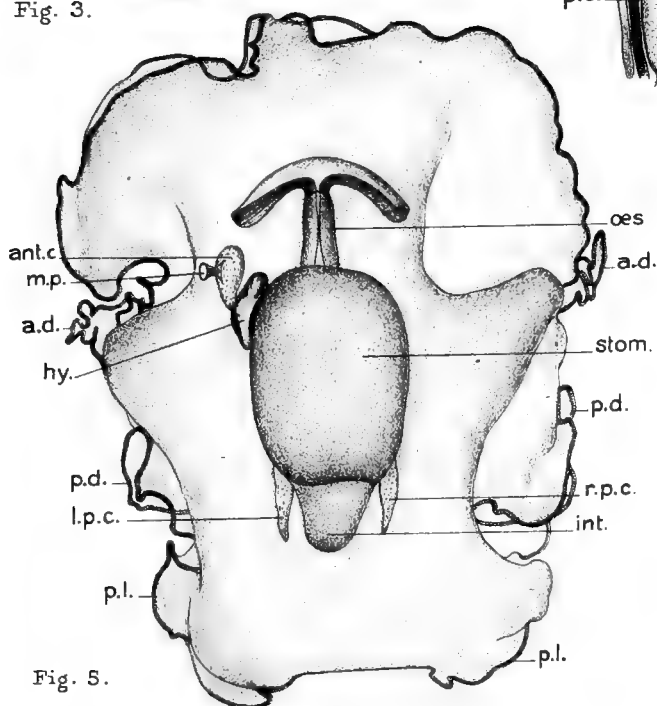


Fig. 5.

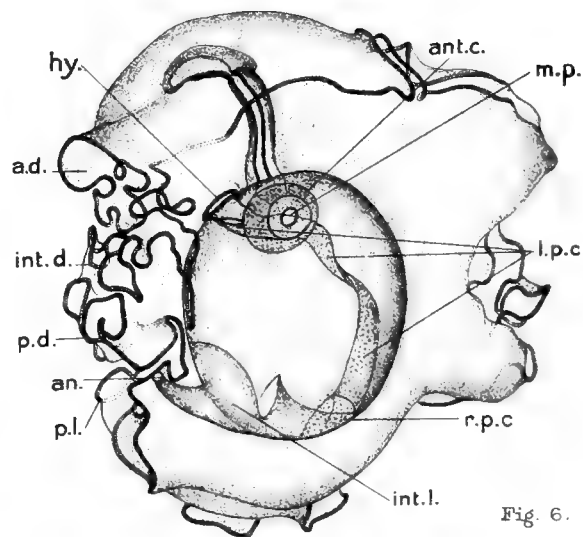


Fig. 6.





Echinoderma, Part II, and Enteropneusta, Plate II.

## PLATE II.

<i>Bipinnaria antarctica</i>	. . . . .	Figs. 7, 8.
<i>Tornaria grenacheri</i>	. . . . .	Figs. 9, 10.

### List of Abbreviations employed.

<p><i>ab. p.</i> aboral plates of starfish.</p> <p><i>a. d.</i> antero-dorsal arm of <i>Bipinnaria</i>.</p> <p><i>ad. cil.</i> adoral ciliated band.</p> <p><i>an.</i> anus.</p> <p><i>ant. c.</i> anterior coelom of <i>Tornaria</i>; conjoined right and left anterior coeloms of <i>Bipinnaria</i>.</p> <p><i>ap.</i> apical plate of <i>Tornaria</i>.</p> <p><i>cil. ep.</i> ciliated epithelium.</p> <p><i>cil. r.</i> ciliated ring of <i>Tornaria</i>.</p> <p><i>coll.</i> collar-groove of <i>Tornaria</i>.</p> <p><i>d. p.</i> dorsal pore of <i>Tornaria</i>.</p> <p><i>gl. ep.</i> glandular epithelium of base of proboscis-cavity or anterior coelom of <i>Tornaria</i>.</p> <p><i>H.</i> heart of <i>Tornaria</i>.</p> <p><i>h. gl.</i> heart-gland.</p> <p><i>hy.</i> hydrocoele.</p> <p><i>int.</i> intestine.</p> <p><i>l. a. c.</i> left anterior coelom of <i>Bipinnaria</i>.</p>	<p><i>l. h.</i> left horn of proboscis-cavity or anterior coelom of <i>Tornaria</i>.</p> <p><i>long. musc.</i> longitudinal muscle-fibrils.</p> <p><i>l. p. c.</i> left posterior coelom.</p> <p><i>m. d.</i> median dorsal arm of <i>Bipinnaria</i>.</p> <p><i>m. v.</i> median ventral arm of <i>Bipinnaria</i>.</p> <p><i>nch.</i> rudiment of notochord of <i>Tornaria</i>.</p> <p><i>oc.</i> eye-pit of <i>Tornaria</i>.</p> <p><i>oes.</i> oesophagus.</p> <p><i>p. d.</i> postero-dorsal arm of <i>Bipinnaria</i>.</p> <p><i>per.</i> pericardial sac of <i>Tornaria</i>.</p> <p><i>p. l.</i> postero-lateral arm of <i>Bipinnaria</i>.</p> <p><i>p. o.</i> post-oral arm of <i>Bipinnaria</i>.</p> <p><i>pr. o.</i> prae-oral arm of <i>Bipinnaria</i>.</p> <p><i>r. a. c.</i> right anterior coelom of <i>Bipinnaria</i>.</p> <p><i>r. h.</i> right horn of anterior coelom of <i>Tornaria</i>.</p> <p><i>r. p. c.</i> right posterior coelom.</p> <p><i>stom.</i> stomach.</p>
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FIG. 7.—A specimen of *Bipinnaria antarctica* viewed from the ventral aspect. The postero-lateral and post-oral arms of the right side (left side of the figure) are broken off, and their former positions are indicated by dotted lines; *ab. p.* organic bases of the aboral (terminal) plates of the future starfish, each carrying two conical spines; *ant. c.* union of right and left coelomic sacs in the prae-oral lobe; *long. musc.* longitudinal muscle-fibres of the arms.

Magnification 16 diameters.

FIG. 8.—A portion of one of the arms of another specimen of *B. antarctica* viewed from the side; *cil. ep.* ridge of ciliated epithelium bordering the groove.

Magnification 140 diameters.

FIG. 10.—A specimen of *Tornaria grenacheri*, Spengel, in the act of metamorphosis, viewed from the dorsal and posterior aspects; *a. p.* apical plate, with *oc.* the eye-pits; *cil. ep.* remnants of longitudinal ciliated band; *cil. r.* posterior ciliated ring; *d. p.* dorsal pore; *gl. ep.* glandular epithelium—rudiment of proboscis-gland; *nch.* rudiment of notochord; *coll.* beginning of collar-groove.

Magnification 22 diameters.

FIG. 9.—The dorsal pore and adjacent organs of the specimen shown in Fig. 10 viewed from the ventral and anterior aspect; *H.* heart; *h. gl.* heart-gland; *per.* pericardial sac; *r. h.* and *l. h.* right and left horns of the anterior body-cavity.

Magnification 60 diameters.

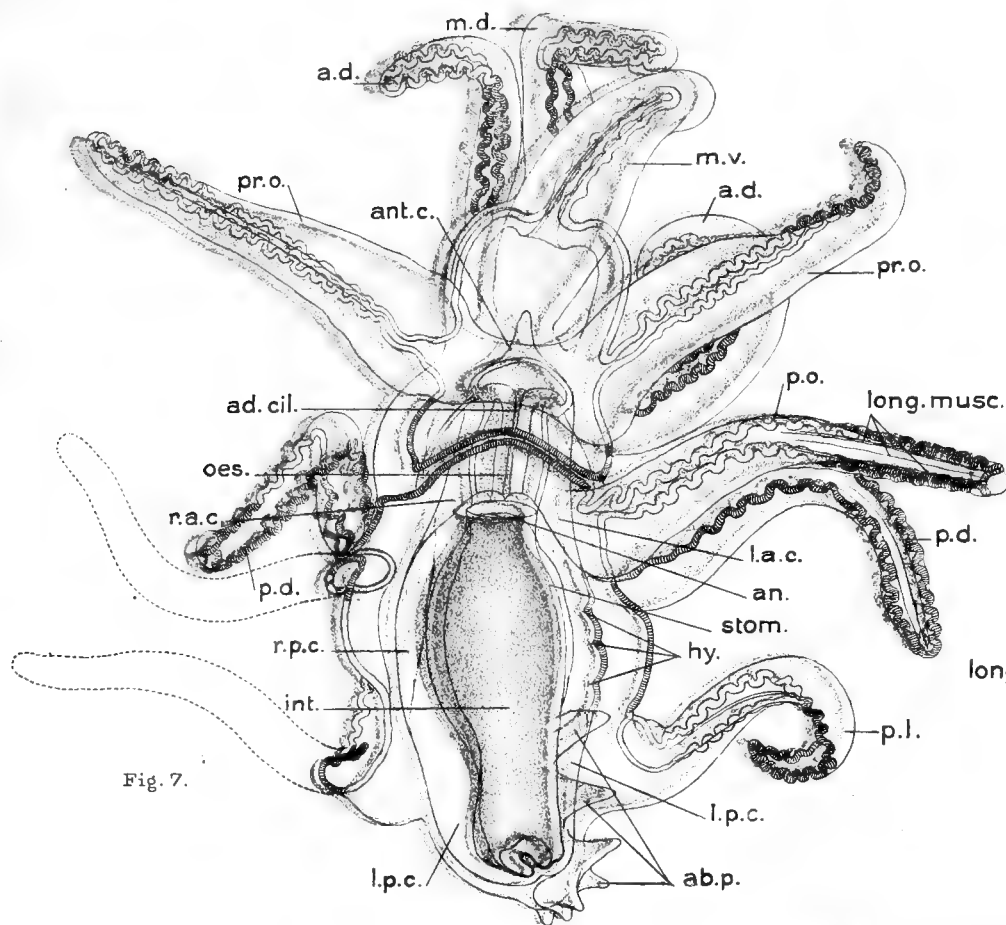


Fig. 7.

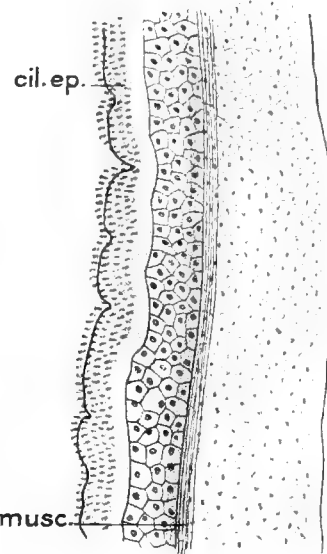


Fig. 8.

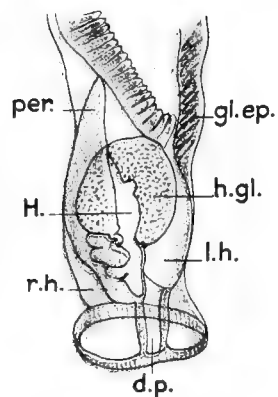


Fig. 9.

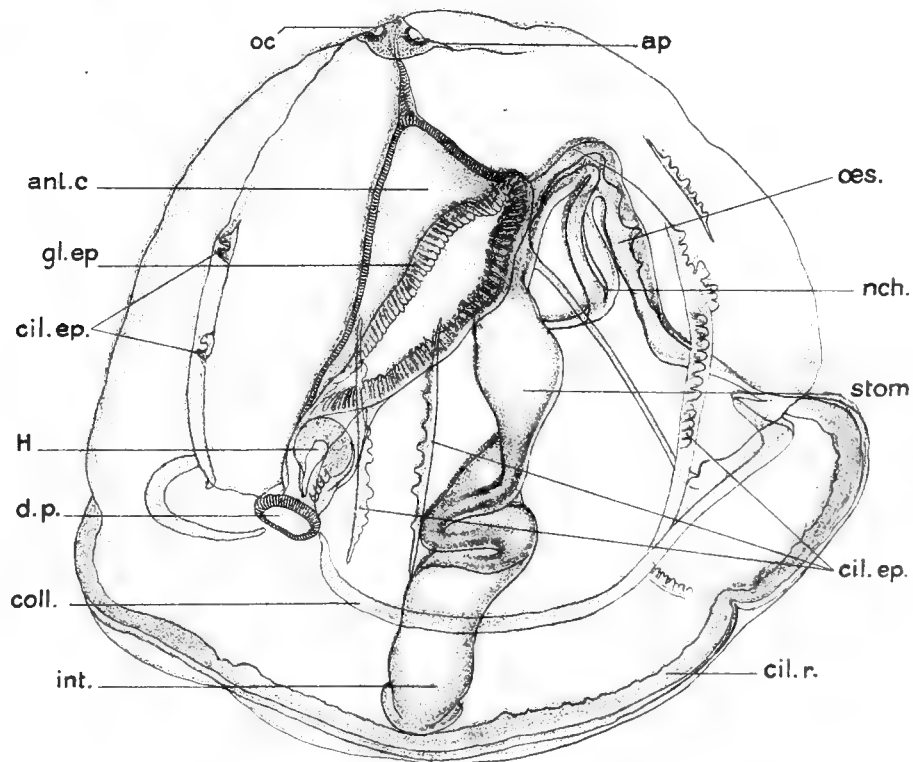


Fig. 10.















